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The Importance of Research and Development for Innovation in Small and Large Canadian Manufacturing Firms

by John R. Baldwin

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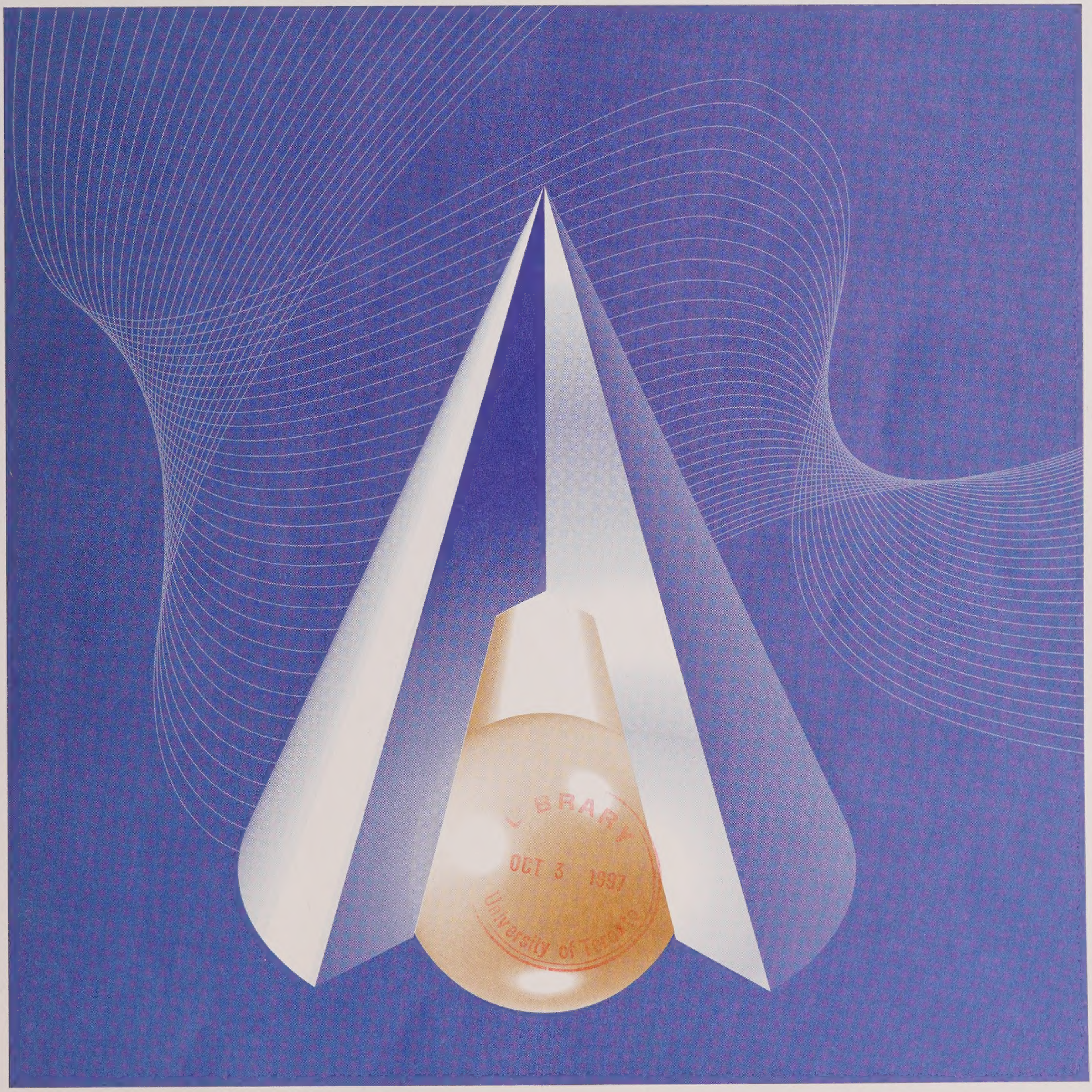

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Statistics Canada
24B, R.H. Coats Building
Ottawa, K1A 0T6

Telephone: (613) 951-8588
Facsimile: (613) 951-5403
e-mail: baldjoh@statcan.ca

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Aussi disponible en français

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Abstract

The debate over the appropriate function of government policy for R&D subsidies brings into focus the different roles that are played by large and small firms in the innovation process. Small firms, it is often claimed, have different tendencies to use R&D facilities than large firms and, therefore, require the development of special programs that are directed at this sector. This paper examines the differences in the innovation profiles of small and large firms, and how R&D intensity and efficacy varies across different size classes. It investigates the contribution that R&D makes to success in the small and medium-sized population and the types of policies that small firms feel are the most appropriate to reduce the impediments to innovation that they face.

The paper finds a number of differences between large and small firms in the tendency to innovate and to use R&D facilities. Small firms can be divided into two groups. The first group consists of firms that resemble large firms in that they perform R&D and generate new products and processes primarily through their own efforts. The second are those who rely upon customers and suppliers for their sources of ideas for innovation. Large firms, by way of contrast, tend to rely more heavily on R&D. While they too rely on networks for ideas, their networks focus more heavily on relationships with other firms that belong to the same firm.

Most of the differences between small and large firms are explained by the fact that firms of different sizes specialize in different parts of the production process. Firms of different sizes serve different niches; they each have their own advantages. Small firms are more flexible but can suffer from cost disadvantages due to scale. They overcome their disadvantages by networking with their customers and by showing the same flexibility in their R&D process that they exhibit elsewhere. They rely less on dedicated R&D facilities and more on the flexible exploitation of R&D as opportunities arise. They also network with customers in order to adopt their suggestions for new innovations.

Keywords: Small versus Large Firms, Innovation, Research and Development

JEL codes: 030

1. Introduction

Since the mid-1970s, the rate of productivity growth has declined in Canada and in many other western nations. This slowdown has generated new interest in the factors that contribute to innovation and policies that can be used to support innovation. Endogenous growth theory has stressed the importance of investments that develop new products and processes and the extent to which government policies may be used to stimulate these investments.

Since small firms' share of total employment in Canada has been increasing (Baldwin and Picot, 1995), attention has been focused on the need for policies to facilitate more innovation in small firms. The growth of the importance of small firms has led to a reexamination of the adequacy of science and technology policies, in general, and research and development (R&D) subsidies, in particular, that are available to this group.

In deciding whether focused efforts to aid small firms' R&D efforts require special policies that are distinct from those designed for large firms, it is essential to assess the differences in the R&D capacity and innovative capabilities of small and large firms. For this reason, this paper examines whether variations exist in the R&D profile and the tendency to innovate of small and large firms.

Most previous studies have focused on the issue of whether there are economics of scale in the R&D function or whether R&D expenditures increase more than proportionately with firm size (e.g., Soete, 1979).[1] Cohen and Klepper (1996a, 1996b), for example, demonstrate that a cost-spreading model of R&D serves to explain why large firms are more likely to perform R&D than are small firms. In a world where benefits of innovation are related to the output of a firm, because of difficulties in appropriating the benefits of innovation in arm's-length contracts, R&D will be less costly per unit of output in large than in small firms. In addition, where there are fixed costs and varying R&D productivity schedules across firms, large firms are also more likely to be doing R&D. Finally, they argue that differences between large and small firms will be greater for process than for product innovations because the nexus between appropriability and size is closer for the former than the latter. This literature implicitly treats firms as entities that are almost homogeneous—differing only in terms of size and R&D propensity.

In these models, firms are treated as having similar cost functions and differ primarily in terms of output. While powerful, these models disregard an important stylized fact—that both large and small firms coexist and that firms are extremely heterogeneous with regards to strategies pursued. Baldwin et al. (1994) and Johnson et al.(1997) demonstrate that small and medium-sized firms differ substantially in terms of their innovative stance and how they carry out innovations. Rothwell and Zegveld (1982), Acs and Audretsch (1990), and Link and Bozeman (1991) also recognize that large and small firms bring different skills to the innovative process.

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1 See Baldwin and Scott (1987) and Scherer (1991) for a summary of the literature.

This paper discusses the nature of the empirical regularities that differentiate the innovative and R&D activities of small and large firms. In doing so, the picture that is developed can be used to substantiate the models of R&D proposed by Cohen and Klepper (1996a).

This paper also sheds light on the firm heterogeneity issue. First, it demonstrates that firms differ in terms of the strategies that are used to exploit innovations. Not all innovations are based on an R&D strategy. Production departments play a very important role in innovation, as Mowery and Rosenberg (1989) have argued. This paper demonstrates that this is particularly true of small firms who tend to emphasize production as opposed to R&D facilities for innovation.

Second, the paper will point out differences in the importance of networks and information transfers. Firms are often characterized as well-demarcated entities, where internal decision-making has replaced arm's-length market transactions (Williamson, 1975). However, the boundary where the firm ends and market-transactions begin varies across different functions. Networks allow the co-operative internal process that is advantageous for some purposes to be extended where it is necessary across firms in certain functional areas without fusing all internal functions of two firms.

Boundaries between firms are fungible and least demarcated in the area of knowledge flows. While knowledge flows so freely that there are appropriability problems (Levin et al., 1987), firms are rarely satisfied that they have the knowledge that is required for their particular circumstances. This deficiency means that information flows often have a firm-specific nature that makes specialized information less than perfectly fungible. Making a process work, as Mowery and Rosenberg (1989) note, requires firm-specific knowledge. This knowledge cannot be easily transferred or incumbents in most industries would not enjoy the advantage that they do.

Information that is ubiquitous and non-rivalrous exists side by side with information that is firm-specific. Both play an important role in the innovation process. Innovation requires the acquisition of knowledge, its transformation, and its commercial exploitation. Innovation makes use in varying degrees of both easily codified, transferable, ubiquitous knowledge on the one hand and firm-specific knowledge on the other hand. The process that is used to develop and exploit the knowledge that is required for innovation differs depending upon the type of knowledge that is transmitted. Knowledge that is generic and easily codifiable is much more easily transmitted and digested than knowledge which is firm-specific and implicit. Different transmission mechanisms are relied upon in each case and alternate institutions (either firms or branches of firms) emerge to handle the process. Kogut and Zander (1993) argue that the multinational firm evolved to transfer tacit knowledge (what came to be called firm-specific advantages in technology, production or other activities). But multinationals are only one form of large firm. It is our contention that large firms develop because they are better able to exploit firm-specific knowledge assets. This paper demonstrates that a critical difference between small and large firms is the extent to which less codifiable information flows are handled. Large firms focus on both internal and external mechanisms to ingest, modify, and distribute firm-specific information. Small firms, by way of contrast, fall into one of two groups. One group concentrates on the organization, control, and coordination of codifiable knowledge and relies on others for a good portion of their information. The other group develops internal capabilities with regards to

R&D that resemble those of larger firms, both with regards to their organizational structure and innovation success rate.

What then are the implications of recognizing the heterogeneous nature of the firm population? It is that differences in R&D intensities between small and large firms, per se, do not provide evidence that small firms are less innovative. Ultimately, it is important to understand how a company's emphasis on R&D affects its innovativeness. Small firms may be just as innovative as large firms but they may innovate in unique ways. In particular, they may not use R&D facilities in the same measure as do large firms. In order to understand distinctions in the role that R&D plays in small as opposed to large firms, this paper examines differences in the sources of ideas that are used for innovation in small and large firms.

Any examination of the causes of innovation must recognize that R&D is only one of the routes that can be used to generate innovations. The innovation system is complex: some firms rely on traditional R&D laboratories, while others develop alliances and joint ventures that allow them to tap into scientific work being done elsewhere. R&D labs are frequently large and costly and economies of scale associated therewith may prevent small firms from constructing their own facilities very frequently.

Elsewhere, when firms are confronted with scale economies in a crucial input, numerous solutions are utilized to offset or overcome the problem. Smaller firms contract with third parties. They form collaborative ventures with competitors. Both of these permit costs to be shared and, therefore, offer potential solutions to the scale problem—though, in the case of R&D, both are second-best solutions for two reasons. First, it is costly to integrate results of outside research into the firm. Second, aligning the objectives of partners who are competitors is often difficult because of an inherent disparity in goals.

Alternately, a firm may form partnerships with other firms that are either upstream (suppliers) or downstream (customers) of itself. These arrangements not only offer advantages with regards to cost sharing, but they also permit the alignment of the goals of each firm.

In comparing small and large firms, it is therefore important not to presume that firms in different size classes must duplicate one another in all respects. Small firms possess advantages in some areas and disadvantages in others. The two must offset one another to a great extent or the two different types of firms could not coexist. Because of their size, small firms may suffer unit cost disadvantages in some areas, but have advantages in flexibility and response time to customer needs. It is important to recognize the differences that are inherent in a heterogeneous environment. Policy intervention in the area of small firms should not be directed at creating miniature replicas of large firms. Rather, it should be focused on areas that offer solutions to problems that small firms have with the innovation process. Therefore, this paper not only examines the connection between innovation and R&D, but also looks at impediments that small firms have with innovation in general.

The paper focuses on differences in patterns of innovation in small firms, pointing out that fewer small than large firms rely on R&D for their innovative ideas. It nevertheless recognizes that a group of small firms do resemble large firms in that they perform R&D and that the issue of R&D effectiveness in this group should be addressed. Therefore, it focuses on the efficacy of the R&D process in those firms that are pursuing this strategy. It does so by asking whether small firms that perform R&D are more or less likely to also report innovations, whether the innovations that are reported tend to be product or process innovations, and whether the innovations vary in importance. It asks not only whether R&D is more likely to lead to innovation but also whether innovation is more likely to be tied to R&D in small and large firms. Finally, it explores differences in the problems that large and small firms find impede innovation and relates these to policy intervention.

The paper uses data on the R&D and innovation profile of small and large firms taken from a recent Canadian innovation survey. Previous work in many countries has relied on data on R&D (Soete, 1979: Kleinknecht, 1987), which is an input to the innovation process, or on patents (Chakrabati and Halperin, 1990), which is one output of the innovation process. Cohen and Levin (1989) have noted the need to move beyond the use of input measures to a more general measure of innovative output than patents. Differences in the propensity to patent across industries (Scherer, 1983) make patents an imperfect measure of innovative output.[2] This has led, more recently,[3] to studies using broader measures of innovation—either specific counts of new products derived from technical journals (Acs and Audretsch, 1987 and 1990) or from innovation surveys (Kleinknecht et al., 1991). This paper makes use of data drawn from a Canadian innovation survey. The advantage of this particular source is that it focuses both on innovation outcomes and the types of processes used to generate the innovations. The survey recognized that innovation differs in several different dimensions. It also takes into account the complexity of the innovation process by examining whether innovations result only or entirely from research and development. Finally, it provides a micro-data base at the firm level that allows connections to be drawn between outputs and inputs so the two can be linked together in a consistent fashion.

2. Data from the Canadian Innovation Survey

The data for the main section of this paper come from the 1993 Survey of Innovation and Advanced Technology (SIAT). The innovation survey investigates both the innovative capabilities of firms in the Canadian manufacturing sector and their research and development activities.

The Innovation and Technology survey was conducted in 1993 using manufacturing firms of all sizes. There were five sections on the questionnaire: section 1 contained general questions, section 2—R&D questions, section 3—innovation questions, section 4—intellectual property questions, and section 5—technology questions (Table 1).

[2] For differences in the propensity to patent in Canada, see Baldwin (1997).
[3] For earlier counts comparisons, see Rothwell and Zegveld (1982)

Three types of units were sampled: plants of larger firms whose head office is located elsewhere, the corresponding head offices of these firms, and small firms that have both their management and plant located in the same spot. In large firms, the first four sections were put to management in head office, the fifth section was addressed to selected plant managers. In small firms, all of the sections were sent to the same location. Consequently, for larger firms,[4] selected plants were sent the technology section and the corresponding head office was sent the first four sections. Together, the head office responses of large firms on general characteristics, R&D, innovation and intellectual property, along with the technology questions answered by their plants, provide a comprehensive overview of the firms' innovative and technological capabilities.

The small firms were handled somewhat differently. In order to reduce response burden, the small firms were separated into two groups. The first group answered sections 1, 3 and 4—the general, innovation, and intellectual property questions. The second group answered sections 1, 2 and 5—the general, R&D and technology questions. In certain sections, small firms were only asked selected questions in order to reduce their response burden.

There were 1595 head offices (answering the first four sections) sampled, 1954 large plants (answering the last section) sampled, 1088 of the first group of small firms (answering the first, third, and fourth section) sampled, and 1092 of the second group of small firms (answering the first, second and fifth section) sampled, for a total of 5729 units sampled.

Table 1. *The Types of Sampling Units*

Firm size	Sections				
	General	R&D	Innovation	Intellectual property	Technology
	questions asked				
Head offices	all	all	all	all	
Small firms - group 1	all		some	all	
Small firms - group 2	all	all			some
Large plants					all

The survey was conducted in several steps. Initially, the firm was contacted to determine who within it (both the head office and the plant) should be sent each section. These individuals were contacted by phone to confirm their ability to respond to the survey. Then the questionnaire was mailed out to the designated individuals. Finally, where necessary, telephone follow-ups were performed. The response rate for the survey as a whole, across all the sections, was 85.5% and ranged from 92.9% in the second group of small firms down to 77.7% in the large plants.

The firms' responses that are reported here were probability weighted to provide an accurate representation of the universe of firms from which the survey was taken; that is, all firms that possessed at least one manufacturing plant.

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4 Larger firms were defined for the purpose of the survey as those that are fully profiled in the Business Register that Statistics Canada maintains. These firms range in size from 20 employees to over 500 employees. Small firms in the survey generally have less than 50 employees and tend to have less information on the register.

When size-classes are being compared in the remainder of this paper, four groups are chosen. The first class consists of micro-firms—those less than 20 employees; the second class consists of small firms—those with 20-99 employees; the third class of medium-sized firms—those with 100-499 employees; the fourth of large firms—those with over 499 employees. While many studies group all firms below 100 employees together, the micro-firms were separated out in this analysis because their profile often differs from the other small firms. However, not all questions in the survey were sent to all small firms, in particular the micro-firms (see Table 1). The number of questions on the survey was reduced for firms that are not profiled by Statistics Canada's business register. These are mainly but not exclusively micro-firms. Subsequent tables reported herein vary in terms of their coverage—with most of the firms in the micro-class sometimes being excluded. When a question covers only the larger firms, the smallest size class—containing the micro-firms—is excluded.

3. Do Small Firms Suffer from an Innovation Gap?

Innovation consists of the commercialization of an important new product or process. Innovation has different dimensions and can be measured in a number of different ways. The Survey of Innovation and Advanced Technology measures this in two ways. First, it asked firms whether they had introduced a product or process innovation in the three years prior to the survey. A product innovation was defined as the commercial adoption of a new product—minor product differentiation was to be excluded. A process innovation was defined as the adoption of new or significantly improved production processes. Second, it asked firms for the percentage of sales in 1993 that came from a minor or from a major product innovation introduced between 1989 and 1991. The two separate questions were placed in different sections of the questionnaire. The first often went to the R&D or product manager; the second went to head office. The first was relatively easy to answer. It may suffer from an upward bias if firms did not restrict themselves just to major innovations as they were instructed to do. The second is more difficult to answer because a breakout of sales data is required that might not have been readily available and for this reason should yield a lower innovation rate. In addition, the percentage of firms answering that they had sales from a major product innovation should yield a lower rate of innovation because it only refers to product innovations. On the other hand, the percentage of firms responding that they had sales from a major or minor product innovation could be above or below the percentage of firms indicating that they simply had a major innovation in the last three years. It could be below the latter to the extent that the question was inherently more difficult to answer and captured only product innovations. It could be above the latter since it captured minor product innovations and the latter was not supposed to do so.

The measures of innovation by size class are presented in Table 2. The percentage of firms that indicate they either introduced or were in the process of introducing an innovation between 1989 and 1993—the year of the survey—is given in row 1. This measure of the probability of being recently innovative (Table 2, row 1) shows substantial differences across size classes. Only 30% of micro-firms were innovative using this criterion, while 63% of large firms were innovative. The percentage of firms that report sales from a major innovation is given in row 2. It too shows differences between the micro-firms and the large firms. However, with this measure, there is little difference between the medium-sized firms and the larger firms. The percentage of firms that reported sales from either a major or minor innovation is given in row 3. Once more there is a major difference between the micro-firms and the largest firms; once again, there is very little difference between the medium-sized and the large firms.

Table 2. *Percentage of Firms With Product / Process Innovation*

Measure	Size class				
	All firms	0-19	20-99	100-499	500+
1) Firms producing product or process innovations	34.2 (2.4)	29.9 (1.6)	38.9 (2.1)	41.2 (3.0)	63.1 (3.6)
2) Firms reporting sales from major product innovations	23.7 (2.1)	20.0 (1.4)	28.1 (2.0)	32.9 (2.9)	36.0 (3.3)
3) Firms reporting sales from major or minor product innovations	43.4 (2.5)	38.1 (1.7)	48.9 (2.2)	58.9 (3.0)	61.9 (3.6)

Note: Standard errors are in brackets.

These numbers show that the micro and the small firms are less likely to innovate than are the medium-sized and large firms. But they generally do not show the largest class to be significantly more innovative than the medium-sized classes—at least with regards to product innovations (Table 2, rows 2 and 3). The largest firms become significantly more innovative than medium-sized firms only when process innovations are added to the picture (Table 2, row 1).

Firms may introduce products without process change, new processes that involve no product change or they may introduce new products and processes simultaneously. Cohen and Klepper (1996b) argue that large firms have a relatively greater likelihood of performing process innovations because process innovations are less saleable in disembodied form and thus the returns to process depend more on a firm's output at any given time.

A breakdown showing the percentage of innovative firms that are product innovators, process innovators, and those that combine product and process innovation demonstrates that the innovative activity of small firms differs from large firms in all three dimensions (Table 3). The three smallest groups are quite similar to one another with respect to the incidence of just product or just process innovations but large firms have a higher probability of innovating in each of these areas. However, the incidence of joint product/process innovation increases monotonically from the smallest to the largest size class. It is also the case that size differentials for firms that engage in process innovations either by itself or in combination with product innovations are greater than for those who engage in pure product innovation. While only 70% of innovative micro firms engage in some form of process innovation, almost all large firms do so.

The percentage differences across size classes are generally much larger for innovations in progress than for innovations actually introduced. This points to differences in the continuity of the innovation process. Large firms are constantly working on innovations and have a large inventory of projects at any one point in time. Small firms survive because of their quickness and flexibility in their general operations. This also extends to their innovative capabilities. They have fewer innovations in the pipeline because they introduce them more quickly.

Table 3. *Percentage of Innovators with Different Types of Innovation (by size class)*

Type	Size class				
	All innovators	0-19	20-99	100-499	500+
Product	34.9	29.5	34.9	31.8	41.6
	(4.8)	(10.3)	(3.8)	(4.1)	(4.3)
Product & process	44.9	21.8	44.4	46.4	51.7
	(5.0)	(8.1)	(4.0)	(4.7)	(4.3)
Process	46.3	43.2	44.5	43.6	57.5
	(5.0)	(11.0)	(4.0)	(4.5)	(4.3)
Product in progress	20.4	14.6	17.8	22.1	27.4
	(4.0)	(7.3)	(3.1)	(3.7)	(3.9)
Product/process in progress	31.8	17.8	33.1	30.5	34.2
	(4.8)	(7.9)	(3.8)	(4.4)	(3.9)
Process in progress	23.0	4.9	19.3	27.9	35.0
	(4.0)	(3.5)	(3.1)	(4.0)	(3.9)

Notes: a) Standard errors are in brackets.
b) A firm may fall into more than one category.

The importance of innovation in any particular size class depends, not just on whether a firm is innovative, but also on how innovative firms in that size class are. Measures of incidence capture the former. Measures of intensity capture the latter. One measure of intensity is the number of innovations produced per innovator. Data on the number of innovations (Table 4) indicate that small innovators do not differ significantly from medium-sized innovators with respect to the number of either new products or processes produced. Indeed, the smaller innovators produce more product innovations per firm than do medium-sized innovators, though they generate fewer process innovations per firm. There is also no significant difference between smaller innovators and innovators in the largest group with respect to product or combined product/process innovations. Smaller innovators do produce a significantly lower number of process innovations per firm than large innovators. Once more, differences between large and small firms are more evident for process than for product innovations.

Table 4. *Number of Innovations Introduced*

Type	Size class			
	All innovators	20-99	100-499	500+
Products	3.4	3.6	2.9	4.2
	(0.6)	(1.0)	(0.5)	(0.8)
Combined	2.4	3.0	1.7	2.9
	(0.3)	(0.6)	(0.2)	(0.7)
Processes	1.9	1.6	2.1	2.4
	(0.1)	(0.2)	(0.2)	(0.3)
Products in progress	2.6	1.7	3.5	4.0
	(0.3)	(0.3)	(0.6)	(1.0)

Note: Standard errors are in brackets.

The importance of an innovation also depends on its significance, which is measured here in two ways: first, by the degree of novelty of the innovation and second, by its importance to the firm in terms of the percentage of sales that the innovation generates.

Novelty was investigated by having respondents describe their most important innovation as a world-first, a Canada-first or 'other' type of innovation (Table 5). The percentage of small innovators that reported world-firsts (11%) is less than for medium-sized innovators (18%), which in turn is less than for large innovators (30%). Small firms, on the other hand, are more likely to implement Canada-firsts and other types of innovations. Small firms are, therefore, not only less likely to innovate; they are less likely to be radical innovators.

Table 5. *Significance of Innovation (% of Innovations)*

Type	Size class			
	All innovators	20-99	100-499	500+
World first	16.2	11.1	18.1	29.9
	(3.5)	(2.2)	(3.6)	(4.1)
Canadian first	33.1	35.4	33.1	30.1
	(4.8)	(3.8)	(4.6)	(3.7)
Other	50.7	53.4	48.9	40.1
	(5.1)	(3.9)	(4.8)	(4.7)
Total	100.0	100.0	100.0	100.0

Note: Standard errors are in brackets.

While the innovations of small firms then are more likely to be of the imitative type, this should not be interpreted to mean that they have less of an impact on the firm. Impact is measured here in terms of the percentage of sales generated by sales of the innovative product. The percentage of sales generated by major product innovations is about the same in micro and small firms as it is in large firms (Table 6, row 3). While small firms may have a tendency to innovate less frequently than large firms, innovation, when it occurs, has just as large an effect on the sales of the small firm. A large firm has a greater breadth of product lines and is continuously seeking innovations; but each innovation in a large firm has less of an effect at the margin since the total effect (% of sales accounted for by major product innovations) is much the same, even though large firms have slightly more innovations per firm. It is also the case that there are no systematic differences across size classes in the importance of minor innovations.

In summary, small and medium-sized firms are generally less likely to be innovative than the largest group. Despite these differences for the population as a whole, when just innovators are examined, there are a number of similarities across size classes. Small innovators are less likely to produce product, process or product/process innovations. Differences across size classes are more pronounced when the frequency of joint product/process innovations is considered, whether these be completed or in progress innovations. Small and medium-sized innovators produce the same number of product innovations per firm as do large firms, though they produce fewer process innovations. The impact of the innovation, in terms of sales, is about the same for small, medium, and large innovators. But, small firms are less likely to have produced world-first innovations; they are more likely to be introducing changes that have already been put in place by others in Canada.

Table 6. *Distribution of Sales by Innovation Category (% by size class)*

	Firm size class				
	All firms	0-19	20-99	100-499	500+
Unchanged product sales	78.8	80.3	77.3	72.6	77.6
	(0.9)	(1.2)	(1.5)	(2.3)	(2.1)
Minor product improvement sales	13.1	11.6	14.7	19.0	14.4
	(0.7)	(0.9)	(1.2)	(2.0)	(1.6)
Major innovative product sales	8.2	8.2	8.0	8.5	8.0
	(0.6)	(0.8)	(0.9)	(1.3)	(1.3)
Total	100.0	100.0	100.0	100.0	100.0

Note: Standard errors are in brackets.

The fact that large firms have a greater probability of innovating, particularly on the process side, and that the intensity of process more so than product innovation increases with firms size, is compatible with, inter alia, the existence of cost-spreading and/or fixed costs associated with the R&D process (Cohen and Klepper, 1996b). It is, of course, also compatible with large firms having lower cost curves or superior R&D productivity.

But there is more to distinguish large and small firms than their position on a cost curve. The two groups focus on different types of innovations. Large innovators would appear to have comparative advantage in producing the most novel (world-first) innovations. There are few differences with regards to introducing Canadian-first innovations. Large-firm comparative advantage (either due to scale economies, scope economies, or cost-spreading) exists more for radical than non-radical innovation.

Despite these differences, small and large firms are affected quite similarly by the innovation process in that new products account for about the same proportion of sales in small and large innovators. This too can be derived from a cost-spreading model, where benefits are proportional to sales. Nevertheless, its implication is important: sales are being renewed by innovation at about the same rate in different parts of the firm size distribution—even though the novelty of that innovation may be quite different.

4. Sources of Innovations

The innovation process differs across size classes with respect to not only the importance of outputs but also the type of inputs that are used in the innovation process. Small and large firms follow unique innovation paths. One of the differences is the source of ideas for innovation.

Innovations are most commonly thought of as resulting from the activities of research and development divisions[5]; but they also originate from the engineering groups who are responsible for the production process. In addition, they may result from vertical linkages with either suppliers or customers. Customers often facilitate innovation by specifying new qualities that are required of the inputs that they purchase as well as by working closely with suppliers to develop the new products. Suppliers can also provide innovations when they develop new uses for their products and actively work with their customers to demonstrate these new uses. While this is especially true of suppliers of machinery and equipment, it is also true of intermediate inputs. Innovative ideas also come from firms that are neither customers nor suppliers. Related firms pass on knowledge. This is one of the reasons for diversification—especially by multinationals. Knowledge is also passed between unrelated firms in the form of licenses for new technology or patents.

While all of these sources provide knowledge that is used for innovation, the knowledge takes quite different forms. Some is easily transmitted from one party to another because the concepts are easily described. This is codifiable knowledge. But other information is more tacit, less codifiable. Knowledge can also differ in its specificity. It can be generic in that it is applicable to a wide range of situations or it can be highly specific to the particular circumstances of a firm (Nelson, 1987, 75). Finally, it can differ in its appropriability. Some knowledge, like that associated with process innovation, is easier to protect than is much of the knowledge associated with product innovation (Cohen and Klepper, 1996a).[6]

Tacit or firm-specific information is associated with higher transfer and transaction costs. In the case of high transaction costs, arm's-length market transactions are often replaced with other arrangements. Von Hippel (1988, ch. 6) outlines how some firms trade in informal know-how. But much know-how has characteristics that make it hard to trade. Williamson (1985) emphasizes that when market transactions are difficult, alternate institutions evolve to solve the problem. An alternative is to extend the boundaries of the firm via growth and mergers so as to internalize the difficulties of transactions in tacit knowledge. One theory of the multinational firm (Caves, 1982) is based on the argument that it is this vehicle that is used to transfer firm-specific knowledge. While the transaction is still costly (Teece, 1977), doing so via intrafirm transfer is less costly than the arm's-length market alternative.

Information sources differ in terms of the extent to which they provide codifiable non-specific knowledge. Customers and suppliers provide information that is either relatively codifiable or non-specific. R&D labs generate information that is less easy to transfer and is often firm-specific (Rosenberg, 1990). While pure research often has certain characteristics associated with a public good in that it provides codifiable knowledge to others, the development component of R&D is much more firm-specific—often being engaged in making a product work.[7] Interfirm networks for the transmission of R&D knowledge evolve when market transfers are less efficient

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[5] For example, studies such as Villard (1959), Hamberg (1964), and Nelson et al. (1967) all focus on the relationship between firm size and R&D. Little or no attention is payed to sources of innovation outside the R&D department.

[6] See Baldwin (1997) for Canadian evidence that Canadian product innovation is much more likely to be protected by patents. Processes are far more likely to be left unprotected except through the use of trade secrets, which suggests that processes receive more natural or inherent protection than products.

[7] For a discussion of the two components, see Cohen and Levinthal (1989).

than internal transfers—where information is difficult to evaluate because of its tacit, specific nature.

Interfirm transfers serve to overcome some of the inefficiencies that develop in the knowledge transfer process. When cost-spreading is prevalent, it allows the benefits of R&D to be spread beyond the firm. When those benefits are passed to customers or suppliers, they have direct feedback effects on the firm that performs the R&D. In these relationships between suppliers and customers, there is less likelihood of opportunistic behaviour, less of a problem with regards to the provision of false information and greater ability to evaluate tacit information. We might, therefore, expect to see symbiotic networks develop to reduce the costs of information creation and transfer.

The types of networks that develop can be deduced from the sources of innovative ideas (Table 7). Differences in the networks that support innovation in small as opposed to larger firms are revealed by the frequency of use that is made of the various sources of ideas for innovation. While R&D is the main source of new ideas for 44% of firms, customers are the source for 46% of ideas (Table 7). However, small and large firms place very different emphases on these two sources. Small firms use R&D much less frequently than large firms (34% and 62%, respectively). On the other hand, small firms rely more than large firms on customers for their innovations (50% and 40%, respectively). The greater emphasis on customers in small firms is also accompanied by a greater emphasis on the sales and marketing department (43% and 37% in small and large firms, respectively). Since the sales department is closely tied to the customer, this difference also stresses the importance of a linkage between small firms and their customers.

Table 7. *Main Sources of Ideas for Innovations (% of Firms by Size Class)*

Source	Size class			
	All firms	20-99	100-499	500+
Management	52.6	53.8	54.8	39.5
	(5.1)	(3.9)	(4.7)	(4.3)
R & D	43.5	33.7	51.8	62.4
	(5.0)	(3.6)	(4.7)	(4.3)
Sales/marketing	42.9	43.3	47.3	37.2
	(5.0)	(3.9)	(4.7)	(4.2)
Production	35.9	36.1	45.5	26.6
	(5.0)	(3.9)	(4.7)	(3.4)
Suppliers	28.3	24.3	34.5	25.4
	(4.6)	(3.4)	(4.6)	(3.8)
Customers	46.1	50.1	45.7	39.5
	(5.1)	(3.9)	(4.7)	(4.3)
Related firms	15.2	11.9	16.7	25.0
	(3.4)	(2.4)	(3.7)	(3.7)
Trade fairs	17.4	18.0	16.7	14.2
	(3.9)	(3.1)	(3.6)	(3.2)

Note: Standard errors are in brackets.

Large firms are more likely to be tied to an external network that is provided by sister firms. About 25% of large firms receive ideas for innovations from a related firm, while only 12% of small firms do likewise. These intrafirm transfers often involve the transfer of the fruits of R&D labs of sister organizations (Teece, 1977). Thus, large firms use internal R&D sources more frequently and tie into an external network that is regulated by intraorganizational ties. Both of these findings suggest that large firms are more likely to depend upon specialized research facilities—either within their own firm or in associated firms. Large firms experience the advantage of specialization of function. Size allows firms to develop specialized R&D facilities. Large firms are also less likely to depend upon managers per se for ideas than are small firms.

In contrast, small and medium-sized firms rely less on R&D, while they place relatively more stress on the technical capabilities of their production department than do large firms. Their innovations come not so much from specialized, separate laboratories as from generalized facilities associated directly with the production process. This accords with the view of Mowery and Rosenberg (1989) on the importance of production personnel as opposed to R&D personnel in the innovation process. They argue that many advances are made first on the assembly line or in the fabrication process. It is only later that these innovations are more fully explored in R&D labs where, for instance, attempts are made to understand the composition of new materials so as to be able to mass-produce them. Small firms concentrate their innovation efforts in the production area. This may occur because these breakthroughs are particularly common for the types of processes in which small firms specialize. It may occur because the comparative advantage of large firms lies in the production of the type of knowledge that originates in R&D facilities.[8] The costs of conducting R&D for large firms are also likely to be lower since specialization of function means that large firms will enjoy cost advantages in the pure R&D function. This cost differential would also lead to the development of a network that links small and large firms. This is confirmed by the importance of external contacts for small firms with their customers—firms that tend to be larger. In addition, smaller and medium-sized firms rely more on management than the largest group—again probably because smaller size militates against specialization of function.

Innovation involves the creation of both new products and new processes. New products often require new technologies. Indeed, some 60% of establishments in the survey that introduced new computer-based fabrication technologies did so in order to facilitate major innovations in the firm. Data on the source of new technologies that are used in process innovations (Table 8) confirm the size-class differences found for innovations as a whole. For the population, research is the least important source of ideas; it is surpassed by experimental development and production engineering. What is more important, while small firms use R&D facilities less than large firms (28% and 44%, respectively), this is not the case for the production and engineering departments.

[8] It is not as easy to attribute this to the cost-spreading explanation of Cohen and Klepper (1996a) because production involves process technology and it is here that large firms are more active innovators.

Table 8. *Main Sources of Ideas for Technologies Associated with Innovations (% of Firms by Size Class)*

Source	Size class			
	All firms	20-99	100-499	500+
Research	8.3	27.8	26.0	43.7
	(4.8)	(3.6)	(4.2)	(4.6)
Experimental development	52.0	51.1	47.7	57.8
	(5.0)	(4.3)	(5.0)	(4.5)
Production engineering	48.6	49.8	65.2	51.1
	(5.0)	(4.3)	(4.7)	(4.6)
Related firms	13.8	13.9	12.5	22.1
	(3.3)	(2.7)	(3.6)	(3.8)
Unrelated firms	16.9	20.7	20.7	13.4
	(3.7)	(3.8)	(4.3)	(3.0)
Customers	11.8	15.5	18.3	8.5
	(3.0)	(3.2)	(3.9)	(2.1)
Suppliers	28.1	24.4	39.9	25.0
	(4.4)	(3.5)	(5.1)	(3.8)
Trade fairs	21.6	17.7	10.9	12.2
	(4.2)	(3.3)	(3.0)	(3.3)

Note: Standard errors are in brackets.

The frequency with which experimental development or production engineering is listed as a source of innovation does not vary in a systematic way across size classes. Once again, unrelated firms are a more important source of innovation for small firms (21%) than for large firms (13%), while large firms are more likely to rely on related firms than are small firms (22% and 14%, respectively).

Comparing Tables 7 and 8, we see that suppliers are an important source of innovative ideas for new technologies as often as they are for both product and process innovation—28% in each case. In contrast, customers are important less frequently for technology ideas (12%) than for innovation in general (46%). New technologies facilitate the development of innovative new processes, while innovation in general includes both product and process technology. The latter differs from the former in that it focuses on product as well as process innovation. The difference in the importance attributed to customers in the two tables, therefore, suggests that customers are particularly useful in helping develop product as opposed to process innovations. While customers are often the source of innovative product ideas, they are less likely to suggest exactly how the idea should be implemented. Conversely, suppliers come up with new ideas, primarily on the technology side.

In the case of both the sources of innovation and the sources of new technology, suppliers are quoted as providing ideas with about the same frequency by both small and large firms. In both cases, smaller firms are more likely to find customers an important source of ideas. Since smaller firms are generally supplying larger firms, this implies that ideas for innovation spread from the larger to the smaller firms via a type of partnership that is based on the mutual dependence that exists between customers and suppliers.

5. Research and Development Activity

Small firms indicate that they are less likely to use R&D facilities to obtain their ideas for innovation than are large firms, because they are less likely to possess R&D facilities and their R&D activities take a different form.

5.1 Frequency of Research and Development

Measures of the incidence of R&D require a criterion that can be used to classify a firm as engaging in R&D. A *performer* of R&D is defined as a firm that directly carries out R&D. A *conductor* of R&D is defined as a firm that carries out *or* funds R&D. The latter would include both firms that perform R&D and those that contract it out to others. This study uses the broader concept (a conductor of research) to define firms that are responsible for and pursue R&D, because it is interested in measuring how many firms benefit from the research and development process. Therefore, it covers firms that conduct R&D and not just those that are R&D performers.

In some surveys, especially those that aim at cross-country comparability, R&D is defined rather narrowly, according to the OECD-sponsored Frascati manual. It is argued (Schmookler, 1959; Kleinknecht, 1987, 1989) and Kleinknecht et al. (1991) that these definitions exclude a significant amount of R&D activity—especially small-firm or informal R&D.[9] Therefore the survey used self-reporting of the existence of an R&D performance as part of information on a firm's innovation profile. This allowed respondents to associate R&D in their firm with knowledge creation used for innovation. Since this may, quite appropriately, entail a broader range of expenditure than is used by the Frascati manual, the survey also requested clarification as to the type of R&D unit and whether the type of expenditure qualified for a tax credit. The last comes closest to the narrower R&D definition normally used.

Firms can undertake R&D regularly or only occasionally. On the one hand, research and development can be an ongoing process that tries to reengineer systems or to develop new products from scratch; on the other hand, it can be a reactive solution to problems that arise from production processes or as new product opportunities arise from customer suggestions. In the former case, R&D is likely to be done continuously. In the latter, it is likely to be done only occasionally. Firms may not set up separate laboratories to constantly search for new products—but they may still devote resources to solving problems or opportunities when they arise.

Research and development, as is measured in the survey, is pursued by two-thirds of the manufacturing population (Table 9). However, a large percentage (41%) carry out R&D only on an occasional basis; only 26% indicate that they have an R&D process that was carried out on an

[9] See also Santarelli and Sterlachinni (1990).

ongoing basis. Most of the firms that are responsible for ongoing R&D are also performers in the narrower sense of the word. Less than 1% indicate that they are responsible for ongoing research, but only list themselves as contracting out R&D. However, about 5% of firms conducting R&D on an occasional basis indicate that they only engage in contract research.

Table 9. *Percentage of Firms Conducting Research and Development*

	Firm size				
	All firms	0-19	20-99	100-499	500+
R&D conducted on an ongoing basis	25.8	19.1	32.3	42.2	52.7
	(2.1)	(1.4)	(2.1)	(3.1)	(3.6)
R&D conducted only occasionally	40.6	39.2	43.4	43.6	32.8
	(2.5)	(1.7)	(2.2)	(3.1)	(3.2)
All R&D originators	66.4	58.3	75.6	85.8	85.5
	(2.4)	(1.8)	(2.0)	(2.3)	(3.2)

Note: Standard errors are in brackets.

There is a difference in the tendency of different sized firms to pursue some form of R&D. Large and medium-sized firms are quite similar—some 86% of both conduct some form of R&D. Small firms are not far behind at 76%. Micro-firms lag far behind at 58%.

There are much greater differences in the extent to which firms of different sizes conduct R&D on a regular basis. Some 53% of firms over 500 employees conduct R&D on an ongoing basis; but this is true of only 42% of medium-sized firms, 32% of small firms, and only 19% of firms with less than 20 employees. In contrast, the smaller and middle-sized groups are more likely to do some R&D on an occasional basis than are the firms in the largest size class. In keeping with their superior flexibility in general, smaller firms also respond to opportunities as they arise by conducting R&D on an occasional basis.

The data confirm the hypothesis of Schmookler (1959) and the Dutch evidence adduced by Kleinknecht et al. (1991) that a substantial proportion of R&D is done casually.[10] It also negates Villard's position that casual R&D is as present in large firms as in small firms. Small firms may be at a disadvantage relative to large firms with regards to regular sized R&D; but their flexibility gives small firms an advantage with regards to occasional R&D.

5.2 Organization of R&D Facilities

Many firms actively pursue an agenda including research and development. This does not imply the widespread existence of separate industrial science laboratories. Research and development can be pursued in a number of different ways—within a dedicated laboratory, throughout the firm in other departments, or it can be contracted out.

[10] Kleinknecht et al. (1991) points out that the international Frascati manual, which is meant to govern the collection of R&D data within the OECD, specifically excludes occasional R&D.

All three methods are important (Table 10). Of those firms indicating that they conduct R&D, 26% do so in a separate R&D department. More than half (63%) indicate that their R&D is done elsewhere in the firm. Firms that contract out R&D work to other organizations make up 23% of those conducting R&D—about the same percentage as have an R&D lab. While there is some overlap between the categories, it is not very significant. About 6% of firms conduct R&D in other departments and contract out research as well. All other combinations are employed by less than 3% of firms.

Table 10. *Organization of Research and Development (as % of firms conducting R&D)*

	Firm size				
Type of R&D facility	All firms	0-19	20-99	100-499	500+
Separated R&D department	25.8	23.4	22.2	36.9	55.7
	(2.5)	(2.0)	(2.0)	(3.1)	(3.6)
R&D in other departments	63.0	61.0	69.9	57.9	48.7
	(2.9)	(2.3)	(2.2)	(3.3)	(3.6)
R&D contracted out	22.5	23.1	20.6	21.8	30.3
	(2.5)	(1.9)	(2.0)	(2.6)	(3.4)

Note: Standard errors are in brackets.

Large firms enjoy the specialization of labour or with cost-spreading that is associated with size; they are much more likely to conduct R&D in a dedicated department than small firms. Some 56% of those with more than 500 employees have a separate unit; the percentage of the middle and smaller classes that do so diminishes steadily until less than a quarter of the smallest two groups have a separate R&D department. This means that small and medium-sized firms that conduct R&D are more likely to do their R&D as part of the work of other departments. There is less of a difference in the percentage of small and large firms that rely on outside companies for contract R&D than there is in the percentage that build a separate R&D department. Small and medium-sized firms resemble one another closely in that from 21% to 23% contract out R&D; but 30% of the largest firms do so.

The type of organization that is adopted is a function of the degree of commitment that the firm makes to the R&D process (Table 11). Some 44% of firms doing ongoing research have separate research departments; less than 15% of firms doing occasional research have a separate R&D department. Despite this difference, it is significant that an ongoing research program does not have to be conducted in a separate R&D department. While only 44% of those firms that are conducting an ongoing program establish a separate R&D department; 59% conduct it in other departments. Small firms in particular are likely to blend R&D into other parts of their organization.

The other major difference between firms conducting ongoing and occasional research occurs in the use of contract research. Firms that only occasionally conduct research are more likely to contract out research.

There is little difference in the tendency of the two groups (those doing ongoing research as opposed to those doing research only occasionally) to conduct their research in departments outside the R&D unit. About 60% of firms doing ongoing research use other departments for this purpose; a slightly larger percentage (65%) of firms that only conduct occasional research do the same. It is significant that an ongoing research program does not necessarily equate with a separate institutional framework for carrying out R&D. It is, nevertheless, the case that a firm making a commitment to ongoing research is more likely to have set up a separate research division than those who only do so occasionally.

Table 11. *Organization of Research and Development*

	Size class				
Of firms conducting ongoing research (% with)	All firms	0-19	20-99	100-499	500+
Separate R&D department	43.9	37.8	40.6	56.9	78.9
	(4.5)	(3.8)	(3.7)	(4.9)	(3.7)
R&D in other departments	59.4	62.8	62.6	50.2	37.3
	(4.5)	(3.7)	(3.7)	(4.8)	(4.5)
R&D contracted out	14.8	12.9	15.9	12.7	25.9
	(3.1)	(2.5)	(2.8)	(2.6)	(4.1)
Of firms conducting occasional research (% with)	All firms	0-19	20-99	100-499	500+
Separate R&D department	13.9	15.9	8.7	18.9	12.0
	(2.8)	(2.2)	(1.6)	(3.7)	(3.2)
R&D in other departments	65.4	60.4	74.5	64.8	71.8
	(3.8)	(2.8)	(2.8)	(4.5)	(4.3)
R&D contracted out	27.3	28.2	25.5	29.8	33.4
	(3.5)	(2.6)	(2.7)	(4.3)	(5.2)

Note: Standard errors are in brackets.

Large firms differ from others in their organization of the R&D function only if they are doing ongoing research. In this group, over 79% of large firms use a separate R&D department, while only 38% of micro-firms do the same. The two smallest size classes are more likely to conduct their R&D in other departments than they are to have a separate R&D department. There is no significant difference in the percentage of large and small firms that contract out research. When occasional conductors of research are examined, few significant differences are found. Small and large firms are equally likely to use a separate R&D department or to contract out research to others.

In conclusion, small firms differ primarily from large firms in that they are more likely to be doing R&D occasionally and, therefore, are less likely to use a separate, dedicated R&D facility.

This suggests that the innovative process in small firms differs from that in large firms in that it is less continuous.[11] This may be partly the result of an agglomeration effect that results from the network between large firms and their smaller suppliers. Large firms often assemble inputs from a myriad of smaller suppliers. As Mowery and Rosenberg (1989) have stressed, R&D relates as much to improving outputs as it does to controlling, refining, and coordinating inputs. If each of the suppliers and the larger assembler has an equal probability of innovating at a point of time, the large firm will experience more change and will need to control it via the establishment of R&D facilities. Even if a small percentage of the suppliers of a large firm change or improve their products annually, the large firm will be continuously experiencing change because it is ingesting this change by the purchase of products from many suppliers. This, in turn, will require it to develop specialized R&D facilities to control this change. There is also an incentive to locate these R&D facilities within the large firm in many cases because it specializes in the coordination of the production process.

5.3 R&D Tax Claims

Some 66% of firms report that they conducted R&D in this survey, though only 26% do so continuously. Because of the liberal interpretation that is probably placed by survey respondents on the concept of R&D, these are upper bounds on the percentage of firms that are engaged in any type of research activity or that conduct a research activity with a substantial R&D commitment.

The number of firms claiming a tax credit for R&D (Table 12) provides a lower bound on the incidence of research activity. To receive a tax credit for R&D expenditure in Canada, firms must undergo a strict audit to confirm that their expenditures meet the criteria laid out in the tax code. About 18% of the firms reporting R&D in this survey sought a tax credit for the R&D work done during the years 1989-91 (Table 12). Either not all firms reporting R&D met the stringent definitions used under the Income Tax Act or some firms do not find it useful to claim their R&D expenditures. The latter could occur because the expenditures are so intertwined with operating expenditures in engineering and production departments that they cannot be separated or because some firms (perhaps the smaller ones) find the costs of the tax program are greater than the benefits.

Table 12. *Percentage of Firms Conducting Research and Development that Claim Tax Credits*

	Firm size				
	All firms	0-19	20-99	100-499	500+
All firms conducting R&D	18.0	11.3	20.8	28.0	56.9
	(2.1)	(1.4)	(1.9)	(2.8)	(3.6)
R&D conducted on ongoing basis	31.4	22.1	34.3	34.7	72.4
	(4.0)	(3.2)	(3.5)	(4.2)	(4.4)
R&D conducted on ongoing basis with a separate R&D department	51.0	30.7	56.3	47.8	81.2
	(11.8)	(12.9)	(10.3)	(9.4)	(6.6)

Note: Standard errors are in brackets.

[11] The evidence that the difference between small and large firms for innovations in progress is much larger than for innovations introduced (Table 3) supports this interpretation.

There are two reasons that firms with a separate R&D department or with an ongoing program are more likely to claim a tax credit. First, these programs are more likely to be associated with the types of expenditures that are eligible for a tax claim. Second, it is more likely that these type of operations facilitate the separation of research expenditures from other expenditures and, therefore, provide for the type of accounting that is required for the tax claims.

Differences in the incidence of tax-credit claims conform to these predictions. A larger percentage of firms that exhibit a greater commitment to the R&D process claim the R&D tax credit. Over 31% of those firms that conduct ongoing R&D claim the tax credit. This increases to 51% for those firms that conduct ongoing R&D and possess a separate R&D facility.

The percentage of large firms claiming a tax credit is much higher than for small firms. Some 57% of large firms that conduct R&D claim a tax credit; only 11% of the micro-firms do so. Some 72% of large firms that continuously conduct R&D claim a tax credit; only 22% of the micro-firms do so. Irrespective then of the category, large firms have a much greater probability of claiming the R&D tax credit than small firms.

5.4 Collaborative Research and Development

Innovation rarely originates entirely within a firm. Ideas for innovation come from a variety of external sources—customers, suppliers, and university researchers. They are championed by members of both management and marketing teams. They are refined by sources such as the production department and by research and development laboratories.

Considerable development work is required before ideas can produce new commercial products or workable new production processes. Because innovative ideas emerge from a variety of sources, outside links between a firm's R&D or production department and external sources will often be used to turn ideas into successful innovations. These links can be made through either contract or collaborative research.

The incidence of contract and collaborative research reveals the diversity of the channels that are used to exploit technological opportunities. Contract research allows a firm to incorporate new ideas when it does not have internal expertise. It works particularly well when the incorporation of new ideas and products does not involve tacit or firm-specific knowledge; that is, where the successful incorporation of new ideas into a firm involves the solution of problems that can be easily evaluated by outsiders. Even where outsiders are called upon for solutions, firms are likely to have internal research programs, since having an internal research capacity is often a prerequisite for the ready adoption of contract research (Mowery and Rosenberg, 1989).

Contract research involves third-party transactions and is a market-based transaction. Collaborative research involves a partnership and, therefore, extends the boundaries of the firm. Collaborative research is a substitute for contract research where third-party or market transactions do not work as well as internalization via the creation of a new entity.

The knowledge created by research has many properties that make it difficult to transfer in third-party transactions. Collaboration potentially allows the creation and transfer of knowledge to be done more efficaciously since the collaborative process permits a firm to train its own research staff and this will facilitate its efforts to incorporate the results of the research into its own production process. Collaborative research also allows costs to be spread across more parties, thereby permitting the exploitation of economies of scale. In addition, it enhances efficiency if it prevents needless duplication of research effort. Finally, by internalizing the externalities associated with new knowledge production in situations where intellectual property rights are weak, collaborative research among competitors can reduce the appropriability problem.

Collaborative research has the disadvantage of requiring the costly coordination of efforts with partners who may not share the same objectives. Collaborative research, like contract research, requires that the resulting research output be successfully reincorporated into the firm. These reabsorption costs may be higher than the cost savings that result from the joint research framework. Not all industries will find appropriability to be a problem, or the size of research scale economies to be large enough to offset the disadvantages of collaborative research.

Despite these problems, a substantial number of firms find that the advantages of collaborative research outweigh the disadvantages. About 16% of Canadian firms that conduct R&D have formed collaborative R&D agreements with other firms at some time in the last three years (Table 13). About 45% of large firms that conduct R&D enter into collaborative agreements; less than 10% of micro-firms initiating R&D do the same. The percentage engaging in R&D collaborative agreements increases to over 52% for large firms that conduct ongoing R&D.

While it was stressed earlier that small firms offset some of their inherent disadvantages of size by participating in networks with others, these partnerships are primarily in the area of easily codifiable knowledge flows. Collaborative R&D agreements involve more difficult to codify knowledge. Here, as with R&D programs, large firms are more actively involved.

Table 13. *Percentage of Firms Conducting R&D With Collaborative Agreements (by size class)*

	Firm size				
Population	All firms	0-19	20-99	100-499	500+
All firms conducting R&D	15.6	10.3	16.7	27.5	45.1
	(2.0)	(1.4)	(1.8)	(2.9)	(3.5)
R&D conducted on ongoing basis	23.4	14.9	23.2	37.8	52.3
	(3.6)	(2.7)	(3.1)	(4.5)	(4.8)

Note: Standard errors are in brackets.

6. The Link Between R&D and Innovation

Large firms are more likely to utilize R&D facilities and are more innovative than small firms by a number of standards. Nevertheless, small firms may not be ineffective performers of R&D. While small firms produce major innovations less frequently than large firms, they also make less use of R&D facilities. The effectiveness of the research and development process in smaller firms requires a comparison of their differences with large firms both with respect to innovativeness and R&D intensity. Ideally, this requires information that would allow a comparison of the value of innovative output to the value of the resources used in the innovative process.

Some have chosen to handle this problem by using employee size to deflate the intensity of innovations (Acs and Audretsch, 1990). If this were to be done here, small firms would be seen to be more effective innovators than large firms. The smallest group of firms are about one-half as likely to innovate as the large firms; but they are only about one-fiftieth the size. Unfortunately, comparisons such as these presume that the amount of resources devoted to R&D is proportional to employment in the firm. Yet, we know small firms are less likely to create a separate R&D lab or do work on an ongoing basis. They are also more likely to obtain their innovation ideas from other, larger firms. Therefore, a comparison of the probability of innovating to the number of employees is likely to be biased against large firms. [12]

Instead, efficacy is measured here by examining differences across size classes in the probability that a firm conducting R&D will innovate—whether R&D is more likely to produce an innovation in smaller firms than it is in larger firms (see Freeman, 1971). Alternately, this section also examines whether an innovation is more closely tied to R&D in larger or smaller firms by investigating whether the percentage of innovative firms that conduct R&D differ across size classes. The first is a type of productivity measure that is derived by asking whether R&D is more likely to result in innovation in smaller or larger firms. The second investigates the extent to which R&D is a necessity in the innovation process—the extent to which innovation is closely tied or linked to R&D.

In order to investigate the effectiveness of R&D, firms were separated into those that conducted R&D occasionally and those that did so on an ongoing basis and the percentage of those that were innovative in each group was calculated for each size class (Table 14). Once again, innovation is defined in three ways: first, as those reporting either a product or process innovation; second, as those reporting sales from a major product innovation; and finally, as those reporting sales from either a minor or a major product innovation. In the first case (Table 14, row 1), only size-class differences for the population of larger firms can be compared because the innovation question was only posed to this group; in the second case (Table 14, row 3), a comparison can be made across the entire population of firms. In order to compare the answers to the two questions, the second is also tabulated (Table 14, row 2) just for the population answering the first.

Of those doing R&D continuously, 56% of firms are innovators based on their responses that they produced a product or process innovation. For the same population, this falls to 44% for those who reported sales from a major or minor product innovation. For the entire population, 64% reported sales from a major or minor product innovation. Generally, the percentage of micro-firms reporting innovations is lower than for small, medium or large firms, but the latter three groups do not differ significantly one from another—with one exception. Large firms have

[12] Perhaps even more problematic with this type of comparison is that it can be interpreted quite differently to suggest that large firms are more important innovators. A large firm, after all, has both a larger share of employment and of sales. If large firms account for more than their numerical share of employment, so do they of sales. Thus their innovation, in that is serves a larger market, could be said to have a 'greater' impact on the consumer.

a much higher success rate than the others using the definition of innovativeness that involves only indicating that product or process innovation had been produced. This accords with our earlier finding that large firms differ more from small firms in their ability to combine process with product innovations.

When just those firms that conduct R&D occasionally are examined (panel B, Table 14), innovation rates are all below the comparable rates for those firms that conduct R&D on an ongoing basis (panel A, Table 14). But these comparisons should be avoided. Occasional R&D should not be expected to result in innovations as frequently as continuous R&D. A fair comparison for the conductors of occasional R&D requires a longer time period over which innovation is measured and that is not available here. Despite this, it should be noted that there are few significant differences in the efficacy of occasional R&D among small, medium, and large firms. It does, however, appear that micro-firms are less efficient.

Table 14. *Innovative Intensity for Conductors of R&D (% of firms by size class)*

	Firm size class				
	All firms	0-19	20-99	100-499	500+
A) Conductors of ongoing R&D					
(i) Product/process innovators (larger firms only)	56.1		52.4	54.0	77.5
	(5.1)		(4.0)	(4.6)	(4.1)
(ii) Sales from major /minor product innovation (larger firms only)	43.6	37.2	49.3	45.7	51.6
	(4.6)	(3.8)	(3.9)	(4.8)	(4.8)
(iii) Sales from major/minor product innovation (all firms)	63.7	54.9	69.6	72.9	73.0
	(4.5)	(3.9)	(3.5)	(4.2)	(4.5)
B) Conductors of occasional R&D					
(i) Product/process innovators (larger firms only)	37.8		41.3	36.7	48.9
	(4.5)		(3.3)	(4.3)	(5.5)
(ii) Sales from major/minor product innovation (larger firms only)	24.1	20.8	27.2	34.2	27.8
	(3.3)	(2.3)	(2.9)	(4.6)	(4.7)
(iii) Sales from major/ minor product innovation (all firms)	47.7	42.4	52.2	63.3	58.0
	(3.9)	(2.8)	(3.3)	(4.3)	(5.5)

Note: Standard errors are in brackets.

Instead of examining whether R&D leads to innovation, one can investigate whether innovation is more closely tied to R&D in small as opposed to large firms. Since we know smaller firms are more likely to obtain their ideas from sources other than R&D, it is possible that focusing just on firms that engage in R&D bias comparisons of efficiency in favour of large firms.

To investigate this issue, innovative were separated from non-innovative firms and the percentage within each group that conducted R&D was calculated. This ratio measures whether innovation only or primarily occurs where there are R&D facilities. Two alternate questions from the survey were used to define innovativeness. In the first, firms were asked whether they had a product or process innovation (Table 15). In the second, they were requested to provide information on the percentage of a firm's sales arising from a major product innovation, minor product innovation, and older products (Table 16). Innovators were defined as those reporting sales from a major product innovation. Once again, it should be pointed out that each question covered a different population. Table 16 includes all micro-firms and thus uses a larger universe.

The first definition of innovation received a higher response rate because it was inherently easier to answer, but it was only put to firms that are generally larger than 20 employees. The latter has a lower response rate but it covers firms both above and below 20 employees.

Some 49% of innovators conduct R&D on an ongoing basis; only 22% of non-innovators do so (Table 15). Some 92% of innovators conduct some form (ongoing or occasional) of R&D, but only 63% of non-innovators do so. R&D performance by itself does not guarantee successful innovations—especially over three-year time horizons. But success is almost invariably associated with some form of R&D performance.

Table 15. *R&D Intensity for Innovators and Non-innovators (% of firms by size class)*

	Firm size class				
	All firms	0-19	20-99	100-499	500+
Innovators (product innovation or reporting process)					
Ongoing R&D	49.4	n.r.	43.2	53.9	64.7
	(4.5)		(3.6)	(4.5)	(4.0)
Occasional R&D	42.4	n.r.	48.9	39.4	25.4
	(4.7)		(3.6)	(4.4)	(3.4)
Total	91.9	n.r.	92.1	93.3	90.1
	(2.6)		(1.9)	(2.3)	(3.0)
Non-innovators					
Ongoing R&D	22.4	n.r.	29.0	34.5	32.2
	(2.3)		(2.5)	(4.2)	(5.9)
Occasional R&D	40.3	n.r.	41.7	46.3	45.6
	(2.8)		(2.6)	(4.3)	(6.5)
Total	62.7	n.r.	70.7	80.8	77.6
	(2.8)		(2.4)	(3.5)	(6.6)

Note: a) Standard errors are in brackets.
b) n.r. stands for not reported.
c) Note that the population of large firms used in this table has a higher probability of doing R&D than the population as a whole that is used for Table 9.

For innovators, the percentage of firms that conduct R&D is about the same for small, medium and large firms—though the extent to which the R&D was done regularly or only occasionally differs substantially across different size classes. Small innovators have about the same dependence on R&D; they differ from large firms in that they conduct their R&D only occasionally rather than continuously. For non-innovators, smaller firms are less likely to conduct R&D than middle- and large-size firms.

A comparison of the relative usage of R&D by size class between innovators and non-innovators reveals that R&D is more likely to be connected to innovation in small firms than in large firms. For example, the proportion of large innovative firms that conduct R&D at 90% is larger than for large non-innovative firms (78%)—a ratio of 1.15 (Table 15). For small firms, this rate increases to 1.34. The difference across size classes in this rate could be the result of a variation in the length of the innovation cycle. It should be noted that innovation in Table 15 is measured over a three-year cycle. Some firms that conduct R&D and that have not succeeded during the period studied may produce innovations later. Therefore, a lower ratio of innovators doing R&D to non-innovators doing R&D is evidence either of a higher R&D failure rate or of a different innovation cycle—one in which a larger proportion of firms do not expect to innovate within the three-year cycle that was examined here. Smaller R&D conductors may be more closely associated with success because the nature of their R&D (occasional) has a shorter gestation period.

Table 16. *R&D Intensity for Innovators and Non-innovators (% of firms by size class)*

	Firm size class				
	All firms	0-19	20-99	100-499	500+
Innovators (with sales of a major new product)					
Ongoing R&D	46.9	39.2	51.8	51.8	68.5
	(4.0)	3.9	(4.1)	(5.4)	(4.9)
Occasional R&D	40.9	45.0	38.5	40.1	22.9
	(4.9)	(4.0)	(3.9)	(5.3)	(4.0)
Total	87.8	84.2	90.3	91.9	91.4
	(3.5)	(3.0)	(2.7)	(3.4)	(4.0)
Non-innovators					
Ongoing R&D	19.1	14.6	23.6	36.5	42.3
	(2.2)	(1.4)	(2.2)	(3.8)	(4.8)
Occasional R&D	40.5	37.9	45.5	45.7	39.4
	(2.9)	(1.9)	(2.6)	(3.8)	(4.6)
Total	59.6	52.5	69.1	82.1	81.7
	(2.9)	(2.0)	(2.5)	(3.5)	(4.5)

Note: Standard errors are in brackets.

The fact that non-innovators in the larger size class are less likely to be conducting R&D than innovative firms and that the difference is not large suggests that the appropriate model to describe the nexus between R&D and innovation for this group of firms is a random chance model—where most large firms conduct R&D but where only some are successful in the three-year period being examined. The percentage of firms conducting R&D is lower for non-innovators for all three-size classes, but it is lowest for the smallest size classes. As a result, the ratio of innovators doing R&D to non-innovators doing R&D is largest for the smallest size class. This implies that innovation is more closely tied to R&D activities in smaller than in larger firms. This would suggest a sorting or heterogeneity model for R&D in smaller firms. Many small firms do not conduct R&D, since they obtain their innovations from other sources. Those small firms that conduct R&D are relatively successful in terms of their ability to produce innovations.

Some of the same stories emerge from Table 16 that uses a larger population and a definition of innovation that involves just sales from major new products. Once again, about the same proportion of small, medium and large firms that are innovators have an R&D facility. This time data are available for micro-firms and the proportion is lower than for the other size classes. Once again, for the non-innovators, fewer firms in the smaller size classes possessed R&D

facilities. Moreover, the differences are larger and more significant than was the case for the previous definition of innovation. The ratio of the proportion of innovators possessing R&D facilities to non-innovators having R&D facilities is much higher in the smaller size classes than in the larger size classes. Therefore, this evidence is more strongly supportive of the sorting model referred to above. When only product innovation is considered, smaller firms sort more cleanly into those doing R&D and being successful innovators and those that can survive by finding their source of competitive advantage elsewhere.

As was pointed out in the first section, it is in the area of product innovation that small firms most closely resemble large firms—probably because it is here that the payoff to innovation is less closely constrained by existing output (Cohen and Klepper, 1996b). New products occasionally offer explosive growth opportunities (at least more than new processes) and a group of small firms are willing to make investments in product innovation in the hope or large returns.

Differences between innovators and non-innovators in terms of the propensity to conduct R&D that is demonstrated above do not extend to the type of R&D delivery system. When just those firms that conduct R&D are chosen and are divided into those that are innovative and non-innovative (using the definition of either having produced a product or process innovation), there are few significant differences in the type of organization that is used to deliver R&D services (Table 17). In each size class, almost the same percentage of innovative and non-innovative firms possess a separate R&D department, or conduct R&D elsewhere, or contract out R&D. The one exception is the large-firm class. Here innovators are more likely to have a separate R&D department than are non-innovators. Specialization of the R&D function within an R&D department then is more crucial only in the largest size classes.

There are, of course, differences in the type of R&D delivery system across size classes that have been discussed in the previous section. Small and large firms have different modes of doing research that are probably related to cost-spreading, the existence of scale or scope economies in the research process that favours large scale operations. But for firms of a given size class, there appears to be no special advantage in choosing one sort of R&D delivery program over another.

Similarities in the delivery system extend to the nature of the cost structure of the innovative process for small and large innovative firms. Innovations require expenditures on basic research, on applied research, on acquiring technical knowledge, on development, on manufacturing startup and on initial marketing efforts. If R&D were relatively unimportant for small innovators, their expenditures in this area might be eclipsed by expenditures elsewhere.

Table 17. *R&D Venue for Innovators and Non-innovators (% of Firms Conducting R&D by Size Class)*

	Firm size class				
Innovators	All firms	0-19	20-99	100-499	500+
Separate R&D department	36.1	19.0	26.1	41.1	65.4
	(4.6)	(9.4)	(3.2)	(4.5)	(3.8)
R&D elsewhere	61.4	72.3	68.4	59.3	38.9
	(4.7)	(9.8)	(3.5)	(4.5)	(3.9)
Contract R&D	22.6	9.9	21.3	23.1	30.0
	(3.9)	(4.9)	(3.0)	(3.7)	(3.8)
Non-innovators					
Separate R&D department	23.6	23.5	20.7	33.7	36.0
	(2.9)	(2.0)	(2.4)	(4.3)	(6.9)
R&D elsewhere	63.4	60.8	70.5	56.9	68.8
	(3.3)	(2.3)	(2.8)	(4.6)	(6.4)
Contract R&D	22.4	23.4	20.3	20.9	30.8
	(2.9)	(2.0)	(2.4)	(3.7)	(6.7)

Note: Standard errors are in brackets.

The breakdown of innovation expenditures is provided in Table 18 for the major innovations of firms. Innovative firms in the smaller size classes do not lag behind those in the larger size classes in terms of the percentage of funds devoted to either basic or applied research. Smaller innovative firms spend relatively more on acquiring technologies and less on development work. Small innovative firms are more outward oriented than large innovative firms that tend to develop technological capabilities within the firm. However, even here, differences are not statistically significant.

Table 18. *Distribution of Innovation Costs by Size Class*

	Size class			
Category	All firms	20-99	100-499	500+
Basic research	7.1	8.3	5.8	5.5
	(0.9)	(1.7)	(1.2)	(1.3)
Applied research	9.1	9.9	9.0	9.3
	(1.0)	(1.6)	(1.8)	(1.8)
Acquisition of technological knowledge	8.5	9.4	6.2	7.6
	(1.5)	(2.7)	(1.7)	(2.3)
Development	32.1	27.7	37.3	32.5
	(2.0)	(2.9)	(3.5)	(3.3)
Manufacturing start-up	34.2	34.8	33.2	35.0
	(2.2)	(3.6)	(3.5)	(3.5)
Marketing start-up	9.1	10.0	8.6	9.9
	(1.1)	(2.0)	(1.5)	(1.5)
Total	100.0	100.0	100.0	100.0

Note: Standard errors are in brackets.

In summary, small and medium-sized firms may be less likely to conduct R&D than the largest firms, but there is little evidence to suggest that, when they do so, they are less likely to produce an innovation. Moreover, it appears that product innovation is more closely tied to R&D performance in small firms than large. In larger firms, both innovators and non-innovators alike are conducting R&D. In smaller firms, innovators are more likely to be conducting R&D than non-innovators.

The cost structure of major innovations for small firms very much resembles that of large firms. Innovations in both small and large firms come from an interfirm network. However, while large firms rely on related firms, small firms are more likely to cultivate special relationships with customers and non-affiliated firms that permit them to develop innovations.

There is, therefore, considerable heterogeneity in the small-firm segment. Some small firms develop an R&D capability to produce new products that will allow them to grow and to supplant existing firms. Other small firms draw on their customers and suppliers for innovative ideas—ideas that are the result of R&D done by these other firms. It is here that R&D spillovers occur.

7. *Innovation and R&D: The Key to Success in Small Firms*

While there are undeniable differences in the degree to which large and small firms make use of an R&D strategy, it would be a mistake to treat an R&D strategy as ineffective in small firms or to conclude that innovation strategies matter for success only in large firms. In the first section, evidence was adduced to indicate that innovation and R&D is less common, though not less effective, in small firms. This section reviews the evidence presented in an earlier study that innovation strategy, especially one based on R&D, is closely related to success in small firms.

Information about three separate, but related, sources of information on a broad range of the *strategies*, *activities*, and *characteristics* of growing small and medium-sized enterprises (GSMEs), along with objective measures of performance, show that innovation is related to success.[13]

Strategies encompass the overall organizational plan that is adopted to meet the firm's goals. The emphasis placed on strategies provides a picture of the competencies of GSMEs. These emphases were measured for each of several different functional areas—management, marketing, financing, and human-resource development. In addition, measurable activities of firms in the area of financing, production, purchasing technology and capital equipment, establishing research and development facilities complement the profile that was developed of firm strategies.

A picture of the competencies of firms in a number of areas was derived from firms' own evaluations of their strengths. Firms ranked the importance of different factors explaining the growth of their company (growth strategies). These factors included management skills, marketing capability, cost of and access to capital, technology skills, R&D-innovation capability, and labour-force skill levels. Scores were based on a scale of 0 to 5: 0 (not applicable), 1 (not important), 2 (slightly important), 3 (important), 4 (very important), and 5 (crucial). In addition, firms provided an assessment of their position relative to their main competitors with regard to

[13] See Baldwin, J., W. Chandler, C. Le and T. Papailiadis. 1994. *Strategies for Success: A Profile of Growing Small and Medium-Sized Business.* Catalogue 61-523ER. Ottawa: Statistics Canada.

price, cost, quality, customer service, labour climate, and skill levels of employees. A six-point scale was used to score each firm's relative position: 0 (not applicable), 1 (much worse than the competition), 2 (somewhat worse), 3 (about the same), 4 (somewhat better) and 5 (much better). Firms also scored (again with a six-point scale) the importance of the developmental tactics that were pursued by the firm in the area of marketing strategy, technology strategy, inputs-sourcing strategy, management practices, and human resources strategy. Finally, firms rated the usefulness (using a six-point scale) of various programs.

Success was measured using an index of growth in market share, profitability, and productivity. The survey sample was then divided into two groups on the basis of each firm's score on the index. Those firms in the top half are defined as the more-successful because of larger increases in their market share, labour productivity, and profitability; those in the bottom half are defined as the less-successful.

a) The Strategies Associated with Success

Success results from choosing the correct combination of strategies and the implementation of activities to achieve strategic objectives. Differences in the mean scores for growth factors, competitiveness-assessment categories, developmental strategies, government programs, innovative activities, training activities and financial structure between the more-successful firms and the less-successful firms indicate which competencies are related to success.

i) The Importance of Innovative Strategies

Almost all of the growth factors (management skills, marketing ability, the skills of their employees, access to capital, cost of capital, ability to adopt technology, R&D, innovation capability, and government assistance) are positively related to success; that is, the mean scores that the more-successful firms attribute to various factors behind their growth are higher than those for the less-successful. The three competencies with the greatest score differences are: R&D-innovation capability, competency in accessing markets, and technological ability, whose mean scores are 41%, 17% and 12% higher, respectively, in the more-successful group. These differences are all statistically significant.

All of these factors are related to the capacity to innovate. R&D is closely associated with the development of new products and processes. New markets often have to be penetrated in order to sell new products; thus, the attention paid to accessing new markets differentiates firms by their innovative marketing ability. Finally, technological capability must be relied on to master new production processes.

In addition to these innovative capabilities, other competencies are also associated with success. Government assistance, marketing, access to capital, the cost of capital, management skill, and employee skills all receive higher scores from those firms that are more-successful. However, in this group, only the difference in the importance attributed to government assistance is statistically significant.

Differences between the mean scores of the more-successful and less-successful firms for each of the areas where competitive assessments were elicited—customer service, flexibility in responding to customer needs, quality of products, employee skills, range of products, frequency of introduction of new products, price of products, cost of production, labour climate, and spending on R&D—show similar results. As was the case with growth factors, the competitive qualities that distinguish the more-successful from the less-successful firms are related to the innovation capabilities of a firm. The more-successful group have a 33% higher mean score for R&D-innovation spending, a 7% higher mean score on the frequency with which they introduce new products, a 5% higher mean score on the range of products offered and an 8% higher mean score on the level of their production costs relative to their competitors. Once again, R&D capabilities are one of the key factors associated with success.

The assessment derived from the growth and competitiveness factors is confirmed by an examination of developmental strategies, which provide a more detailed picture of the nature of the strategies or activities that are pursued by more-successful firms in five major areas: marketing, technology, production efficiency, management and human resources.

Once again, an aggressive innovation policy serves to distinguish more-successful from less-successful firms. In terms of technology strategies, the more-successful group assign significantly higher scores to two aggressive strategies—a 21% higher mean score for "developing a new technology" and a 16% higher mean score for "refining the technology of others". A 7% higher mean score is assigned to "improving own existing technology". Adopting the least aggressive strategy—"using the technology of others"—has no significant association with success.

In the area of production strategies, more-successful firms place a significantly greater emphasis on the importance they attribute to using new materials (a 14% higher mean score), using existing materials more efficiently (a 19% higher mean score), and reducing energy costs (a 15% higher mean score).

The choice of government assistance may be looked upon as an additional strategy adopted by a firm. Detail on the usefulness of a set of programs that are delivered by federal, provincial and municipal governments was elicited from the sample of firms. The importance of R&D tax incentives, government procurement, training programs, industrial support, export incentives, and market-information services was ranked on a scale ranging from 0 (not applicable) to 5 (very important).

Four of the six generic government programs receive higher scores from the more-successful firms. The two with the greatest and most significant differences are export incentives (which receives a 54% higher score) and R&D tax incentives (with a 35% higher score). The scores on market-information services and industrial support are also positively related to success but the differences are less significant.

(ii) The Importance of R&D Activities

Innovative strategies distinguish the more- from the less-successful. This is also the case with innovative activities. A larger percentage of firms conducting R&D are found in the more-successful group of firms. Only 6% of the less-successful firms have an R&D unit; 12.6% of the more-successful firms have such a unit. The respective percentages for those taking advantage of R&D tax incentives are 15.3 and 24.3.

The intensity of investment in R&D is also higher in more-successful firms. For just those firms reporting investment expenditure, the ratio of R&D to total investment in the less-successful is 12.0%; in the more-successful, it is 21.2%. This calculation is affected by the relative incidence of those firms doing no R&D. For just those firms that report R&D investment, the ratios are 50.8% and 57.3%, respectively. It is, therefore, evident that the incidence of R&D (whether or not it is done) differs more than the intensity of R&D activity (how much is done, if it is done) between the more- and less-successful groups of firms.

(iii) Innovations and the source of ideas

Measures of research and development expenditure provide information on only one of the inputs into the innovation process and thus only one facet of innovation. Investigating the sources of innovation provides an alternate measure. GSMEs ranked a number of sources for innovative ideas on a scale from 0 (not applicable) to 5 (very important). The sources of innovations differ between the more-successful and the less-successful firms. Firms that are more-successful place significantly greater stress on innovations originating from internal technical sources. The more-successful group assign a 73% higher mean score to innovations from the R&D unit and a 42% higher mean score to the production unit. Sources of innovation stemming from the parent, from Canadian patents, and from foreign patents receive 41%, 47% and 52% higher mean scores respectively from the more-successful firms. The only non-technical source that receives a higher score is the marketing department (an 18% higher mean score).

In conclusion, innovation is consistently found to be the most important characteristic associated with success. Almost all of the strategy questions that relate to innovation receive higher scores from the more-successful group of firms than from the less-successful group of firms. This is also the case for innovative activities. Whether a firm possesses an R&D unit, its expenditure on R&D relative to total investment, and its R&D-to-sales ratio are all related to success. R&D in small firms is critically associated with success. Other areas related to technological adoption, production costs, the use of new materials inputs and innovations in management (just-in-time and process control) are also important.

8. Impediments Associated with Innovation

The results of the 1993 Canadian Innovation Survey reinforce those derived from the Growing Small and Medium-Sized Enterprise (GSME) Survey. As was discussed in the last section, the latter study demonstrated that R&D is invariably associated with innovation. An R&D innovative strategy has a significant impact on a firm's success. It is associated with greater market share and greater profitability. It is closely associated with producing successful innovations.

Information relevant for policy formation is available in both studies. Making use of government programs is associated with success—but primarily in those areas that involve broad framework policies, such as support for R&D and export programs. These are policies that complement private-sector success strategies. Firms that give greater stress to innovation are more likely to make use of these programs. They are also more likely to be winners. In these cases, private-sector winners pick government programs rather than the reverse, which considerably reduces the onus on governments when they try to pick the winners themselves. Governments must still formulate their offerings so that they are broadly supportive of innovation and maximize the likelihood that they will indeed be chosen by winners rather than losers.

While R&D strategy is important, it is not the only route taken by small firms to achieve success. An R&D strategy is more important in manufacturing than in the service sectors where innovations are less connected with traditional investments in machinery and equipment and process technology. Technology is important, but so too is the development of human capital (Baldwin and Johnson, 1996). Policy that ignores the human component ignores the importance of the contribution that investments in training make to those industries where most of the innovative capital of a firm consists of brainpower as opposed to machinery and equipment.

Equally important, it should be recognized that small firms suffer major problems in areas where the existence of externalities has led governments to develop support policies. Small firms are heterogeneous actors that generally suffer disadvantages in information collection, processing and analysis. It is proficiency in these areas that has allowed large firms to grow and prosper. Large firms have developed methods to create and transmit tacit knowledge—through the establishment of R&D labs and the forging of ownership links across units. By way of contrast, small firms are more likely to rely on codifiable knowledge that is transmitted from customers and suppliers. As a result, they face quite different problems. Relatively greater deficiencies are commonly seen to exist for small firms with regards to information on market development (especially export markets), and new technologies. Large firms have developed networks via inter-company relationships and via extensive links to both customers and suppliers. Small firms, however, tend to focus relatively more on the links to unrelated parties that do relatively well in transmitting easily codifiable information. They have a less developed system of acquiring the type of tacit knowledge that large firms transmit from sister firm to sister firm within the same organization. As a result, small firms are also seen as suffering relatively greater problems when it comes to developing interfirm co-operative agreements.

Table 19. *Impediments to Innovation (% of Firms by Size Class)*

Category	Size class				
	All	0-19	20-99	100-499	500+
Lack of skilled personnel	45.9	44.1	49.2	48.3	43.4
	(4.8)	(3.6)	(4.2)	(5.0)	(4.7)
Lack of information on technologies	30.5	30.8	30.9	33.5	20.4
	(4.4)	(3.3)	(3.9)	(5.0)	(4.3)
Lack of information on markets	37.2	42.7	29.8	31.5	30.0
	(4.7)	(3.6)	(3.9)	(4.7)	(4.6)
Lack of external technical services	20.0	21.1	21.2	14.3	12.7
	(3.9)	(2.9)	(3.6)	(3.2)	(3.4)
Barriers to interfirm cooperation	18.9	21.8	17.2	14.3	6.1
	(3.8)	(3.0)	(3.3)	(3.5)	(2.6)
Barriers to university cooperation	7.6	9.3	5.2	5.5	7.1
	(2.5)	(2.1)	(1.7)	(2.0)	(1.7)
Government standards	30.6	34.0	26.8	21.7	31.0

Note: Standard errors are in brackets.

These deficiencies were confirmed by the Canadian innovation survey. The frequency with which firms specified that problems offered an impediment to innovation is presented in Table 19. Firms of all sizes cite training problems most frequently; but there is very little difference in the severity of this problem across size classes. Human resources provide the most critical source of imbedded information and all firms believe this is the most important problem that they face. For most of the other problems, the smaller firms more frequently indicate that a particular impediment is a problem for them than do large firms. Both a lack of information on technologies and a lack of technical services are seen to be greater problems by micro-, small, and medium-sized firms than by large firms. Firms in the three smaller groups also perceive that interfirm co-operation is a problem more frequently than large firms who benefit from intrafirm cooperative agreements. This should be set in context of the lower frequency of interfirm R&D collaboration of smaller firms (Table 13). Finally, lack of information on markets is a greater problem for the micro-firms. All of this confirms that small and large firms differ substantially in terms of their ability to acquire and transform information. But it should be stressed that the information gap exists primarily for technical information and services, the type of information that is essential for process technology.

Innovation involves changes in both products and processes. Indeed, one of the greatest differences between the innovative behaviour of small and large firms lies in the degree to which small firms lag behind larger firms in process technology (Baldwin and Sabourin, 1995). Process technology is an important key to success (Baldwin, Diverty and Sabourin, 1995). The fact that small firms perceive that they suffer information gaps in this area and that it is an important factor in conditioning success in small firms suggests that one of the highest payoffs for those government policies that focus on externalities and additionality lies in this area.

9. Conclusion

The debate over the appropriate function of government policy for R&D subsidies brings into focus the different roles that are played by large and small firms in the innovation process. Small firms, it is often claimed, have different tendencies to use R&D facilities than large firms and, therefore, are less innovative.

The paper demonstrates that, in Canada, small firms are less likely than large firms to introduce new products and processes. Similar differences are observed between large and small firms with regards to the frequency of R&D activity. Small firms are less likely to engage in R&D, just as they are less likely to innovate. While there are fewer innovators in the smaller size classes, those smaller firms that do innovate resemble larger innovators in several dimensions. There are few differences in the number of product innovations per innovative firm across size classes. The innovation cost structure is much the same. In addition, major product innovations in small innovative firms account for just as large a percentage of their sales as in larger innovative firms. There is, nevertheless, a tendency for smaller firms to produce fewer innovations that are novel.

Most of the stylized facts on relative innovativeness or R&D intensity accord with the existence of cost-spreading, scale economies, and/or productivity differentials. They also support the notion that it is on the process rather than the product innovation side that large firms possess their greatest advantage. But the paper also stresses that there alternative ways to thinking about populations of firms than portraying them as homogeneous units, all with the same cost functions. The picture that has been developed here is also compatible with life-cycle models of a firm's development (Rothwell and Zegveld, 1982), which suggest that populations are made up of firms at different stages of their product life-cycle. There will be small firms at the beginning of their life-cycle that are specializing in product innovation, and large firms that are later in the cycle that perform both product and process innovation.[14] The evidence presented here can be interpreted to simply depict a population that has been generated by this type of process. In doing so, the paper also emphasizes the nature of dependencies that develop between firms because of the importance of information flows for economic activity. Both small and large firms draw heavily on outside sources for their innovations. Small innovators do, however, rely on different sources of ideas for innovation. Ideas for innovation come from a number of sources—R&D, customers and the marketing or sales department, the production division or from suppliers. Large firms use R&D much more frequently than do small firms, 63% and 34% respectively. Large firms are also more likely to rely on an external research network, through a relationship with a related firm or to engage in collaborative research with other firms. On the other hand, small firms rely relatively less on the R&D department and relatively more on the technical capabilities of their production departments than do large firms. Small firms also depend on networks—but these networks rely more heavily on customers and their marketing departments for innovations.

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[14] See Baldwin and Johnson (1998) for a study that investigates how firms differ across these stages in their life cycle.

While small firms rely less on the R&D department and more on linkages to other unrelated firms, the differences for the percentage of firms in a size class that conduct any form of R&D—on a continuous or an occasional basis—are not large. In contrast, small firms are much less likely to conduct R&D on a continuous basis. Small firms are significantly less likely to set up a separate R&D unit and much less likely to take advantage of R&D tax subsidies. There is, therefore, more of a difference in the way that R&D is conducted in small firms than whether it is conducted at all. Large firms have regularized the R&D process in order to shape their environment, while small firms use it to exploit opportunities in their environment when the need arises. Their customers or suppliers bring many of these opportunities to their attention. Small firms exhibit the same flexibility in their R&D that they show in many of their other operations. These differences suggest that large firms, as a whole, have mastered the need to create and acquire non-codifiable information that is difficult to incorporate into the firm. Small firms, as a whole, utilize information sources that are more easily transmitted through supplier relationships.

These differences in the sources of ideas, when taken together, suggest that the information and transmission processes vary considerably across size classes. Large firms rely more on tacit, non-codifiable information that is developed within the firm, either in their own R&D laboratories or in the R&D laboratories of related firms. Some smaller firms do the same, but the group as a whole does not do so with the same frequency. The rest of the small-firm group relies on information that is more easily codifiable and transmitted from customers and suppliers. The information networks of small firms are less developed than for larger firms.

When the efficacy of the R&D process is compared across small and large firms, few differences emerge. In those firms that conduct R&D, the percentage that report an innovation is about the same for small, medium and large firms. There is a higher success rate for those with an ongoing R&D operation than for those conducting occasional R&D, irrespective of the size class; but this is partly a statistical phenomenon that is likely related to differences in the type of R&D performed. Smaller firms tend to be more likely to conduct occasional R&D than continuous R&D, which causes small firms to look less productive if all those who conduct any form of R&D are aggregated together.

An examination of the extent to which innovation comes only from R&D shows that innovation is more closely associated with R&D in small firms than large firms. In large firms, both innovators and non-innovators alike are conducting R&D. In small firms, product innovators are more likely to be conducting R&D, but non-innovators are less likely to be conducting R&D. More large firms are doing R&D and firms sort into those that are successful and not-successful conductors of R&D—where success is assessed as the production of an innovation. On the other hand, smaller firms sort more cleanly into those doing R&D who are successful innovators and those who can survive by finding their innovations elsewhere.

Small firms then can be divided into two groups. The first group consists of firms that resemble large firms in that they perform R&D and generate new products and processes (relatively more of the former than the latter) primarily through their own efforts. The second are those who rely upon customers and suppliers for their sources of ideas for innovation. Large firms, by way of contrast, tend to rely more heavily on R&D. While they too rely on networks for ideas, their networks focus more heavily on relationships with other firms that belong to the same firm.

Evidence shows that despite differences in R&D intensity, the success of small firms depends critically on their innovative capabilities—especially in the areas of R&D. Small firms also benefit from the R&D done in large firms because a larger proportion of their innovations are the result of liaisons with their customers. All of this means that subsidies for R&D directly aid the most dynamic small firms that are conducting R&D and also aid this group indirectly because of the spillovers from large firms to small firms.

Despite the importance of R&D for innovation, there are other areas where public policy can develop special policies for small firms. These are areas where small firms have indicated that they face special problems. Small firms perceive that externalities are relatively important in the area of information on technologies, on markets, and on technical services. They also perceive that there are significant barriers to interfirm cooperation. This is a particularly serious problem since this is the method that they use most frequently for developing new ideas for innovation.

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